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Research Article

Axial Length Changes after Glaucoma Deep Sclerectomy Surgery

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Abstract

Aims: The aim of this study is to determine the longitudinal change in the eye´s axial length (AL), produced by a non-penetrating deep sclerectomy (NPDS).

Methods: 22 subjects diagnosed with glaucoma were included in the study (14 at one-month follow-up and 8 at a follow-up of at least one year), who had undergone combined glaucoma and cataract surgery. Compare with a control group of 20 eyes follow up, 14 of them for one month and 6 for one year. The relationship between changes in IOP and AL were retrospectively analyzed. The intraocular pressure (IOP) measurement was taken using contactless tonometry (Topcon CT-80). The AL and depth of the anterior chamber (ACD) was calculated using optical biometry (IOL Master, Carl-Zeiss). An assessment of the refractive status was performed through subjective refraction before and after surgery.

Results: An average reduction in IOP of 10.14 ± 6.67mmHg (p<0, 05) and an average decrease in AL of 0.15±0.06mm (p<0, 05) were observed in the one month follow-up group. Similarly, the group with a follow-up of at least one year shows an average reduction in IOP of 8.50 ± 5.95 (p<0, 05) an average decrease in ALof 0.10 ± 0.09mm (p<0, 05). No Statistical differences were found between the Spherical Equivalent calculated and found after the surgery

Conclusion: After undergoing NPDS, there is a reduction in AL, which becomes more pronounced with decreasing IOP and decreasing time since the operation. This reduction in IOP observed could account for these longitudinal changes (34%). The moderate linear correlation (r>0.3, p<0.05) allows us to predict the reduction in AL according to the following formula: Reduction in AL (mm) = 0.065 + (0,006xReduction in IOP).

INTRODUCTION

Glaucoma is one of the leading causes of irreversible blindness in developed countries, being the second cause of blindness in the world [1]. It´s a complex and multifactor optic neuropathy characterized by a progressive loss of retinal ganglion cells and their axons, coinciding with a reduction in the thickness of the retinal nerve fiber layer. It is considered one of the most frequent pathologies in ophthalmology and it is thought that less than 50% of Primary open-angle glaucoma cases are diagnosed in developed countries [2].

One of the primary risk factors for developing glaucoma is a high intraocular pressure (IOP), and initial treatment consists in reducing the IOP with a pharmacological treatment. When medication is not effective, surgery proves effective in long-term IOP control [3]. In most cases, due to the advanced age of the patients, glaucoma surgery is combined with cataract surgery. Advances in medicine and surgery have contributed in the evolution of conventional glaucoma-filtering surgical techniques. Non-perforating deep sclerectomy (NPDS) yields positive results with reduced surgical trauma [4]. Krasnov published the first reports describing the procedure in 1968. The technique was further revised by Fyodorov in 1984 and subsequently perfected by Arenas, Dahan and Mermoud in the nineteen-nineties.

The aim of this study is to determine the change in the eye´s length, known as its axial length (AL), produced by NPDS. The reduction in IOP could be the primary cause for the longitudinal changes of the eye. Quantifying these changes will allow us to improve the calculation of the IOL in cataract surgery, whether it is carried out combined with NPDS oral one. Following glaucoma surgery, there is an increased incidence of cataracts [4]. To properly calculate the intraocular lens (IOL) we must take into account the longitudinal optical changes that could be produced subsequent to the sizeable reductions in IOP after glaucoma surgery. Finding a relationship between changes in IOP and AL could supply new information on the complex treatment of glaucoma.

MATERIALS AND METHODS

A follow-up of glaucoma-operated patients was conducted by taking their IOP and measuring the AL and depth of the anterior chamber (ACD). All tests were carried out at the Hospital of Torrevieja.

The IOP was measured through contactless tonometry, using a pneumatic tonometer *(Topcon CT-80).* The average of three measurements was obtained. The AL and ACD were calculated using optical biometry *(IOL Master, Carl-Zeiss Meditec; Dublín, California, USA. Version 4.02.0473)*, which allows for greater precision [5] than other methods and does not require contact with the eye. The signal-to-noise ratio (SNR) has been greater than 2. The IOL calculation was according to the SRK/T formula, include in the IOL-Master Software. The power of the IOL was the closest to emetropia. Visual acuity (VA) eye chart at 5 meters was used, obtaining the measure in decimal notation. An assessment of the refractive status had been performed through Objective / subjective refraction before and after surgery.

For the analysis of changes in refraction, most papers suggest to use the spherical and astigmatic components M, J_0 and J_{45} or vector components power, a metric to describe the widely used refractive errors in clinical practice. Power vectors were proposed and developed by Humphrey, Keating, Harris and Thibos [6]. Unequivocally, represent refractive eye unlike what happens in traditional refraction. For the statistical description of the distribution of ametropias, the use of this mathematical formula has many advantages because each component is mathematically independent of the others. Once these parameters were obtained, the value of blurring (B) was calculated, a simplified estimation of the magnitude of the refractive state. An anterior and posterior pole control was carried out using biomicroscopy, noting the transparency of the media, the initial state and changes in the filtering bleb. The papillary excavation was also subjectively assessed with a +90D lens. Standard periodic controls were established by visual field tests and optical coherence tomography (OCT). These have helped to determine that there has not been any additional glaucomatous damage. Combine glaucoma and cataract surgery was carried out on cataract patients with a Glaucoma not controlled with full medication or stable with three or more medication. Two control groups who had only undergone cataract surgery were established, with the results observed after one month, and after one year.

This surgical technique (NPDS) is demanding and difficult to perform, has a relatively long learning curve. The surgery was carried out by two experienced surgeons (KSP and JIBS), following the same methodology. All the surgeries were performed using peribulbar anesthesia in 50% of cases and subtenon anesthesia in the other 50% of cases. The use of *intra operative anti metabolite* Mitomycin (MMC) 0.02mg/mL was used in 86% of the cases. After cauterizing the sclera, the superficial scleral flap was delineated (using a marker or compass) measuring 5x5 mm in the case of a quadrangular flap, or 5x5x4 mm in the case of a trapezoidal flap (figure 1). The superficial flap was created at 1/3 of the total scleral thickness and subsequently the deep flap at 90% of the total scleral thickness. Then the peeling and dilatation of Schlemm´s Canal was carried out. Finally, the non-absorbable implant Esnoper V-2000 (AJL, Alava Spain) was placed in the supra choroidal space, no stiches used and the scleral flap was closed by apposition or by suture. The conjunctive close with Nylon 10-0, 2 to 4 stiches. Cases in which the trabeculo-descemetic membrane has a perforation, were converted to a trabeculectomy were not included in the study. After the glaucoma surgery, the *phaco emulsification* was carried out and the IOL was inserted. Once the auxiliary limbal paracentesis was performed, visco elastic was applied and a primary incision of about 2, 2 mm was made. This incision varies in position depending on the eye and on the surgeon. A continuous curvilinear (circular) capsulorhexis was carried out, through which the cataract was *hydro-dissected*, hydro-delaminated, and phaco emulsified. Irrigation was applied

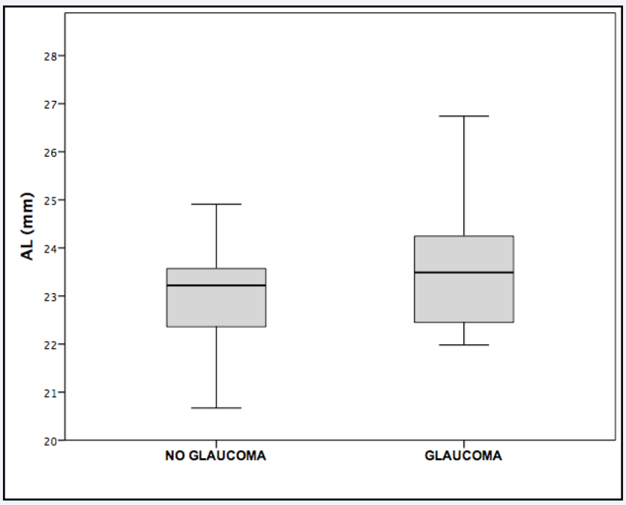

Figure 1 AL preparative on eyes with and without diagnosis of glaucoma. Approximately 20% of cases diagnosed with glaucoma exhibit AL higher.

Table 1: Descriptive characteristics of patients undergoing combined surgery (cataract and NPDS)

	Combined surgery (n=14)	Combined surgery (n=8)
Time from surgery (months)	1.54±0.77	13.08±3.47
Age (years)	74±6.90	71±6.22
OD/OS	9-May	4-Apr
Man/Woman	5-Sep	2-Jun

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and the cortical remnants were aspired, then the IOL was inserted into the bag through the primary incision. After ensuring that the IOL was centered and stabilized, the visco elastic is washed out, the *intra cameral antibiotic* is applied, and the incisions are sealed by hydration.

Patients

A total of 42eyes of 42 patients had been included in the study, 22 eyes diagnosed with glaucoma and 20 eyes of the control group only with cataracts. Patients with postoperative complications, those with a missing data, patients with a best-corrected visual acuity (VA) of less than 0.1 on a decimal scale pre-surgery and those with macular alterations, were excluded. All study patients had Cataract and Glaucoma not controlled with medication therefore combined surgery was performed. Hypotensive treatments prior to the intervention varied from mono-therapies to combined therapies. The mean of drops was 2,36 ± 0,90–14 combined cataract and glaucoma surgery eyes were follow up and control for one month and 8 eyes at one year. The preoperative AL, ACD, PIO, subjective refraction and VA data were retrospectively collected from all patients. After the surgery, the measurements were taken again. Table (1) shows the primary characteristics for these two groups.

The control group of cataract-operated patients (phaco-emulsification and IOL implantation) included 14 eyes monitored at one month and 6 eyes monitored at one year (Table 2).

Statistical Analysis

Given to the small size of the different groups studied, in order to compare the changes produced in AL and IOP with the surgery, the Wilcoxon rank test was used, a non-parametric test that evaluates the differences in related samples. Likewise, in order to carry out the comparisons between different groups (the study group and the control group), the Mann-Whitney U test was used, for independent samples. The relationship between a reduction in AL and a reduction in IOP or elapsed time has been studied through regression analysis. The contrasts in hypotheses were bilateral in all cases, with a significance level of 0.05. The calculations were made using the program SPSS for Windows (version 20, SPSS Inc., Chicago).

RESULTS

The average AL for study patients is 23.52 ± 1.12 mm (n=22), with respect to 23.09 ± 1.20mm (n=20) for those patients without diagnosed glaucoma (Figure 1). Table (3) shows the average values for pre- and post-operative IOP and AL for the one-month follow up. The preoperative IOP was 19.00 ± 6.58mmHg while the postoperative IOP was 9.14 ± 2.63mmHg with an average decrease of 10.14 ± 6.67mmHg. The average decrease in AL was 0.15 ± 0.06mm, showing a reduction in all cases.

Similarly, Table (4) shows the same variables at one year. The average preoperative IOP was 22.36 ± 4.20mmHg and after the surgery, it was 14.43 ± 2.79mmHg with an average change of 8.50 ± 5.95mmHg. The reduction in AL was present in 6 of the 8 cases of the study group, being -0.10 ± 0.09mm. In the control group, the preoperative IOP was 16.36 ± 3.05mmHg and 13.86 ± 3.53mmHg, for the groups at one month and one year, respectively. The changes observed after the surgery were smaller than those observed in the study group, decreasing an average of 3.86 ± 2.35mmHg in the one month group and 2.00 ± 1.92mmHg at one year. With respect to the AL, the results obtained were similar, with an average decrease of 0.06 and 0.08mm, respectively. In order to study the correlation between the change in AL and the reduction in IOP, the data have been arranged into two groups: combined surgeries and the control group. Figure (2) shows the regression analysis for these two groups. There is a statistically significant and moderate correlation (Pearson correlation coefficient r=0.585; Spearman rho r=0.581. Significance of 0.004 y 0.005 respectively for a significant correlation at a level of 0.01) in the studied group. The correlation is positive, indicating that the greatest reductions in IOP produced greater reductions in the AL. The coefficient of determination (R^2) indicates the proportion of variability of the variable reduction in IOP in the linear model obtained. Consequently, according to this model, the reduction in IOP explains the 34% reduction in AL (R^2=0.343). As this moderate linear correlation exists (r>0.3 is associated with the correlative contrast $p<0.05$) we complete our statistical study through a simple linear regression analysis. A linear regression line can be obtained, allowing for the prediction of the reduction in AL possible according to the following formula: *Reduction in AL = 0.065 + (0,007xReduction in IOP).* According to the refractive results, no statistical differences were found in spherical equivalent calculated and the result obtain (Table 5). In groups,

Table 2: Descriptive characteristics of control group (cataract surgery).

	Control group	Control group
	(n=14)	(n=6)
Time fromsurgery (months)	1.09 ±0.52	11.54±2.73
Age (years)	72±7.93	71±4.96
OD/OS	6-Aug	2-Apr
Man/Woman	8-Jun	4-Feb

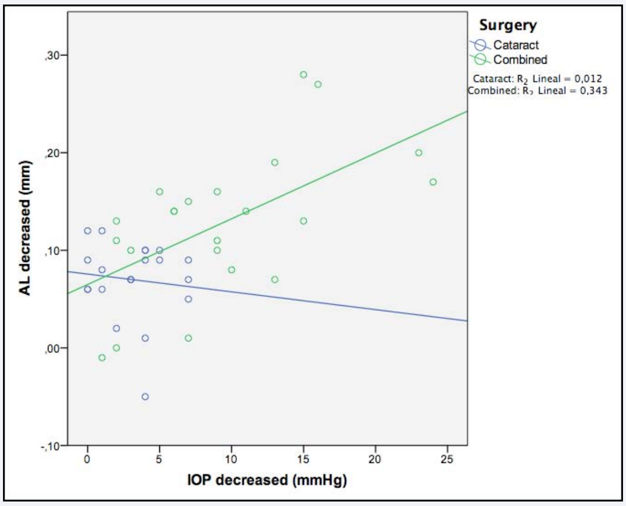

Figure 2 Association between IOP decrease and decrease of AL in the study and control group. A positive relationship is observed in study group.

combine surgery and control (p=0.780; U-Mann Whitney). No differences in the spherical or cylindrical power obtain after the surgery. Therefore after the surgery the tendency is to neutral power, there is a change in Visual acuity and blurring index after the surgery been no statistically significative (Table 6). With respect to the change in the anterior chamber depth, a significant increase ($p<0.05$) was observed in all cases. This change, in the case of eyes, which underwent a combined surgery, was 0.85 ± 0.45mm. In the control group cases, the observed change was 0.97 ± 0.47mm. (p=0.597; U-Mann Whitney) (Figure 3).

DISCUSSION

The association between glaucoma and cataracts is more common, in the aging population, and the increased risk of developing cataracts associated with some types of glaucoma. A better long-term control of IOP has been demonstrated after a trabeculectomy combined with cataract extraction than with a trabeculectomy alone [7,8].

After considering this, and encouraged by the low rate of complications for NPDS, various studies have been published which assess the results of this type of surgery combined with cataract surgery. As a result, NPDS surgery has a lower postoperative complication rate and a reduction in IOP comparable to a trabeculectomy. Moreover, the reduction in IOP is greater if it is combined with the use of MMC [9]. The AL measurement should be taken into account, since calculating the IOL is directly dependent on longitudinal factors of the eye. Knowing that significant changes can be undergone in the eye´s longitudinal parameters, especially of AL, as well as how to predict them, is indispensable to improve the calculation of the power of the IOL. After glaucoma surgery, changes in corneal astigmatism are produced [10], as variations due to modifications in the longitudinal parameters, in AL and ACD. With respect to the changes in ACD, Cunliffe finds a decrease after first week in 94% of the eyes operated, being greater than 0.5mm in 80% of cases [11]. After three weeks, 56% continued to demonstrate a depth lower than the preoperative one, although that difference was greater than 0,5mm in only one eye. These changes are correlated with the changes in the spherical equivalent and are observable in eyes with a high preoperative IOP. The data collected in our study are not comparable, given the combination with cataract surgery. This leads to a significant increment in the ACD due to the extraction of the crystalline lens [12]. Early studies that relate changes in AL after glaucoma surgery date to the nineties [13]. Although the surgeries performed those years, trabeculectomy, and the AL measurement methods used (ultrasound) are different from ours, the data obtained indicate an important relationship between longitudinal changes and IOP. Subsequently, Cash well after having refractive surprises in patients previously operated of trabeculectomy, studied the longitudinal changes in the eye in patients successfully operated of filtering surgery [14]. These possible changes in AL could account for unexpected refractive defects present in those patients after undergoing cataract surgery. The axial length reduced by an average of 0,423mm after trabeculectomy in 62 eyes (the period studied was 22.5 ± 17.5 months). The preoperative factors associated with the greatest reduction in axial length were young age, myopia, exposure to anti metabolites, and a post-trabulectomy reduction in IOP greater than 30mmHg. There were no significant changes in AL observed in eyes (n=15) that had subsequently undergone cataract surgery. It should be taken into account that AL measurements via techniques involving contact (ultrasound) produces deformation due to the pressure which could lead to lower measurements [15]. In 2005, a study carried out by Francis found a minor but statistically significant reduction in AL in patients who underwent a trabeculectomy (n=39) and with a drainage device (n=22), with follow-up at one week, one month and three months afterwards [16]. This reduction, greater in eyes with postoperative hypotonia, is associated with a reduction in IOP, but not with age, sex, type of surgery and preoperative AL. A greater change in AL was discovered one week after surgery, which returned to preoperative values after 3 months. Although it is associated with a reduction in IOP, this decreased over time. A formula to predict the change in the AL after 3 months was developed: *Reduction in AL (mm) = -0.199 + 0.006* x IOP *Reduction + 0.008* x *final IOP.* A greater reduction is observed when using ultrasound biometry, a contact technique, which can cause deformation upon measuring postoperative hypotonic eyes or those with a low IOP. It should be noted that the precision of measurements using this technique is lower than with contactless interferometric biometry *(IOL Master, Zeiss-Humphrey)*.

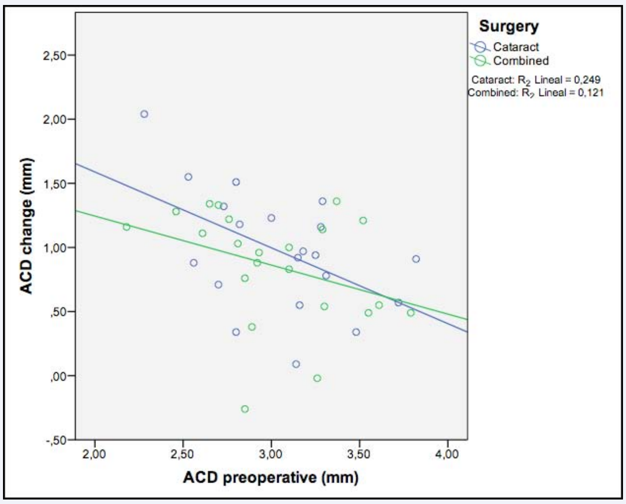

Figure 3 Change produced in ACD after the surgical procedure. No statiscally significant differences between the study group and control group.

Law compares combined surgery, trabeculectomy and cataract, with cataract surgery alone, observing a greater change in AL (measured with inter ferometric biometry, IOL Master) in the case of combined surgeries [17]. This reduction was related to a significant reduction in IOP, due in part to the influence of the MMC, with respect to the cataract surgery. This reduction was statistically significant in both groups, yielding values of 0.117 ± 0.057mm in the case of combined surgery (n=24), and 0.075±0.038mm in the cataract group (n=16). These findings are comparable to those obtained in our study. Although a change in axial length and corneal curvature were found, subsequent refractive readings after a combined operation did not differ significantly from the expected refraction. At present, there is only one study, by Üretmen *et al.,* which assesses these changes

Table 3: Mean values of IOP and AL preoperative and postoperative in study group (combined surgery; NPDS/cataract) and control group (cataract), per month. Mean changes caused in these values after surgery.

		Preoperative	Postoperative	Mean change	P value
Combinedsurgery	IOP(mmHg)	19.00±6.58	9.14±2.63	-10.14±6.67	0,001
(n=14)	AL(mm)	23.73±1.28	23.58±1.28	-0.15±0.06	0,001
Control group	IOP(mmHg)	16.36±3.05	12.47±2.29	-3.86±2.35*	0,002
(n=14)	AL(mm)	22.95±1.12	22.88±1.13	-0.06±0.04†	0,002

*IOP unchanged in two eyes
†LA higher in one eye after surgery
p value calculated with Wilcoxon test

Table 4: Mean values of IOP and AL preoperative and postoperative in study group (combined surgery; NPDS/cataract) and control group (cataract), more than a year. Mean changes caused in these values after surgery.

		Preoperative	Postoperative	Mean change	P value
Combinedsurgery	IOP(mmHg)	23.00±5.24	14.50±2.50	-8.50±5.95	0,012
(n=8)	AL(mm)	23.38±0.99	23.29±0.97	-0.10±0.09	0,028
Control group	IOP(mmHg)	13.67±3.93	12.33±3.08	-1.33±1.51*	0,066
(n=6)	AL(mm)	23.27±1.29	23.19±1.30	-0.09±0.04	0,027

*IOP unchanged in three eyes
p value calculated with Wilcoxon test

Table 5: Mean values of spherical equivalent target expected after surgery and spherical equivalent obtained.

	Target EE (D)	Postoperative (D)	P value
Combined surgery	-0.16±0.24	-0.15±0.55	0.851
one month	-0.14±0.18	-0.16±0.64	0.889
one year			
Control group	-0.05±0.36	0.00±0.68	0.638
one month	-0.27±0.32	-0.44±0.92	0.6
one year			

p value calculated with Wilcoxon test

Table 6: Refractive combined surgery data before and after surgery, one month and one year group; M, J0, J45, power vectors; B, final blurring vector; AV, visual acuity in decimal scale.

	Preoperative	Postoperative	P value
	one month	one month	
	one year	one year	
M (D)	-0.03±2.34	-0.15±0.55	0.875
	0.16±2.03	-0.16±0.64	0.833
J0 (D)	0.06±0.71	-0.30±0.47	0.294
	0.20±0.30	-0.10±0.81	0.327
J45 (D)	-0.17±0.54	-0.23±0.39	0.552
	0.30±0.81	-0.20±0.63	0.401
B	1.95±1.47	0.80±0.41	0.004
	1.68±1.35	1.03±0.59	0.263*
AV	0.52±0.26	0.73±0.16	0.006
	0.53±0.29	0.81±0.27	0.043

*statistically significant in the control group
p value calculated with Wilcoxon test

in eyes undergoing NPDS [18], with a one-month and one-year follow-up for 30 eyes. A reduction in AL was observed after one month, associated with higher reductions in IOP. Conversely, the AL after one year was close to its preoperative value even though the IOP was still significantly lower. Although the AL readings were carried out using applanation biometry, which could yield unreliable results, in the contralateral eye and the control group no significant changes were observed. This data reveals that there is a reduction in AL after glaucoma surgery. Initially, it seems to be related to an important reduction in IOP, but in the long term, a regression to preoperative AL values is produced, while maintaining the reduction in IOP. This leads us to think that the IOP is not the primary factor responsible for the reduction in AL as was initially anticipated. Our findings are similar to those found by Law and Üretmen, as to the significant reduction in AL, associated with a decrease in IOP. In our study, a decrease in IOP was observed in all cases for the combined surgery group, with a subsequent reduction in the axial length. Only one case was observed in which the preoperative and postoperative values were the same. This is associated with the lowest reduction in IOP (2mmHg) in the group observed for longer than one year (at 18 months). The greatest reduction in IOP was observed in 2 patients from the one-month group, with reductions of 24 and 23mmHg respectively. This reduction was associated with the greatest reductions in AL, 0.17 and 0.20mm respectively. Current research highlights this reduction in AL after a trabeculectomy, with a significant decrease in IOP, as a result of an increase in choroidal thickness [19,20]. Our results show no refractive differences after the surgery referred to the astigmatic component in a total of 38 patients after the combine surgery NPDS and cataract seeing at 1 and 3 months similar to the results found by Corcostegui *et al.,* [21]. If the change in AL would be considered for the calculations of the IOL, the results would be more in the positive value. No refractive surprise was found even in the cases with more decrease of IOP and AL Authors relate AL with glaucoma [22] and find a significant rate of primary open-angle glaucoma (POAG) and normotensive glaucoma (NTG) in eyes with AL ≥ 25mm. This was observed in 83.7% of patients with POAG (n=137) and in 92.6% of patients with NTG (n=87). This demonstrates a strong relationship between glaucoma and AL. Our data do not present significant differences (p=0.782; test de U Mann-Whitney) with respect to the axial lengths of those patients who had glaucoma and those who did not. The differences observed between the averages for both groups are negligible. However, a greater trend was observed in the group of patients diagnosed with glaucoma, towards higher values.

CONCLUSION

We find a significant reduction in AL and IOP after surgery. The reduction in AL is higher in combined surgeries, and is associated with a greater reduction in IOP. This shortening of the eye becomes more pronounced the higher the reductions in IOP and the lower the time elapsed since the operation. Our results show that the reduction in IOP accounts for 34% of the reduction in AL, yielded by the regression equation: *Reduction in AL = 0.065 + (0.007xReduction in IOP).* AL should be taken into account, especially in cases of combined surgery, which are currently being performed more often. Adjusting this figure to obtain a closer calculation of the IOL could prove necessary in cases for which a large reduction is predicted after surgery. This would be especially important in patients with a high IOP. Not all the patients included in the study, who were diagnosed with glaucoma, have shown any subjective or objective changes in the progression of the disease after surgery. We can estimate a disease stability parameter through the AL values. Patients who show a reduction in AL of at least 0.15mm after the onset of the hypotensive treatment, with a corresponding reduction in IOP within the target value, will not have the damage to the optic nerve increased. In the same way, if after one year this reduction is least to 0.10mm. Studying retinal thickness and choroids at the macular level with high-resolution images, using OCT, is supplying new data and establishing new parameters for the future study of glaucoma.

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